Crop Tree Release Improves Competitiveness of Northern Red Oak Growing in Association with Black Cherry

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ABSTRACT: *In 1993, a crop tree study was established in a pole-sized stand consisting of black cherry (*Prunus serotina *Ehrh.) and northern red oak (*Quercus rubra *L.). Black cherry was the predominant species in the stand and appeared to be on the verge of virtually eliminating northern red oak based on its greater height growth potential. To assess crop tree management for maintaining the competitiveness of oak in this situation, the stand was compartmentalized into treated and untreated areas and crop trees were selected. In the treated areas, crop trees received a three- or four-sided crown-touching release. Individual tree characteristics were measured following the growing seasons of 1993 and 10 years later. Crop tree release resulted in slowing the height growth of codominant black cherry, but not northern red oak. Ten-year mean height growth of northern red oak exceeded that of released black cherry, but not that of unreleased black cherry crop trees. Crown expansion and diameter at breast height (dbh) growth also increased as a result of crop tree release for both species, but black cherry clear stem development was suppressed. Based on increment core analysis, dbh growth of released northern red oak crop trees in 2003 was about twice that of unreleased northern red oak, although black cherry treatment related differences in radial growth were no longer present. Ten years after crop tree release, northern red oak crown class distribution improved and black cherry crown class distribution was unchanged. These results suggest crop tree management will improve northern red oak competitiveness in pole-sized stands when growing in association with black cherry and, perhaps, other fast growing species. North. J. Appl. For. 23(2):77–82.*

Key Words: *Quercus rubra, Prunus serotina*, crop tree management, height growth.

Crop tree management is a flexible, intermediate stand management technique especially suited to managing forest stands with variable stem qualities and relative species values and diverse species assemblages. Applying area-wide thinnings in such stands may fail to focus thinning operations on the most desirable trees. In contrast, crop tree management is intended to focus management efforts on only the trees that satisfy management objectives, whether those objectives be related to timber, wildlife, esthetics, water quality, or some combination thereof (Perkey et al. 1994).

Previous research has shown that crop tree management reliably increases diameter and crown growth in both precommercial (Smith and Lamson 1983, Lamson and Smith 1989, Lamson et al. 1990, Miller 2000) and commercial operations (Stringer et al. 1988, Ward 2002). The results of crop tree management with respect to height growth are less consistent. In a number of cases, some species of crop trees receiving a crown-touching or greater release may exhibit decreased height growth (Trimble 1974, Lamson and Smith 1978, Miller 2000). In older stands, inhibition of height growth is usually not a management concern because most height growth occurs during earlier stages of stand development. For example, 50% of northern red oak (*Quercus rubra* L.) height growth occurs during the first 25 years of an 80-year rotation (northern red oak site $index_{50} = 70$) (Schnur 1937). Moreover, while older hardwood trees continue to grow in height, although more slowly, merchantable height may have already reached a maximum due to stem form characteristics. However, in young, even-aged stands, height growth is crucial to maintaining a competitive position in what is usually a closed forest canopy, and any release that has a negative effect on height growth may be counterproductive to selecting crop trees. Lamson and Smith (1978) attempted to pick crop trees at age 9 years in

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an even-aged stand in West Virginia and found that the effect on height growth varied by species and crown classification at the time crop trees were chosen. They concluded that release did not prevent crown class deterioration and that crop tree selection should wait until codominant trees were about 25 ft tall. In stands that met the 25-ft height recommendation, Miller (2000) found height growth varied by degree of release for black cherry (*Prunus serotina* Ehrh.) and yellow-poplar (*Liriodendron tulipifera* L.). Trees receiving a crown-touching release maintained their relative crown positions after 10 years, but height growth was reduced when black cherry and yellow-poplar crop trees received a heavier thinning. In the same study, northern red and chestnut oak (*Q. prinus* L.) height growth was not affected by a conventional crown-touching release.

It is often assumed that height growth is relatively independent of stocking. This is evident in commonly used height/age site index equations. These equations are predicated on the height of codominant trees at a convenient base age, regardless of past or present stocking. The usual assumption is that trees used to estimate site index have grown in fully stocked stands and were codominant trees throughout their development. However, species grown at low stocking levels and with weak epinastic control, such as most eastern hardwoods, often exhibit reduced height growth (Nixon et al. 1983, Ward 1995). In a southeastern Ohio study, Allen and Marquis (1970) concluded that short-term height growth of northern red oak and yellow-poplar was maximized at about 70% stocking. These results suggest that in some cases, complete crown release of individual crop trees may make some trees less likely to persist in stands where height growth is essential to maintaining a dominant or codominant crown class.

It is not uncommon for many third-growth stands to be dominated by fast growing, shade-intolerant species such as yellow-poplar or black cherry and for oak (*Quercus* spp.) to be present as scattered individual stems, if at all. Forest stands that included a significant oak component during both old-growth and second-growth stages often are characterized by a greatly diminished oak component following second-growth harvesting. The oak component often declines even further as the stand progresses through the stem exclusion stage (Miller et al. 2001, Brashears et al. 2004). The decline of oak in older stands is also well documented, and many old-growth oak forests are undergoing changes to more shade-tolerant species (Abrams 1992, Schuler 2004). To combat this trend, silviculturists continue to explore ways to develop abundant understory oak to promote oak competitiveness following regeneration activities (Brose and Van Lear 1998). However, such methods may require 10–20 years prior to final overstory removal. This period may deter acceptance of such practices in forests characterized by short ownership tenure and/or inadequate silvicultural planning (Fajvan et al. 1998). Therefore, to meet common timber, wildlife, and diversity goals, forest managers need techniques for increasing the survival rate of insufficient densities of oak common in many young third-growth stands.

In this study, I examine the potential of using crop tree management in a pole-size stand of predominantly black cherry with a lower-than-desired density of northern red oak on a productive site in north-central West Virginia. My objectives were to evaluate conventional crop tree management practices to improve the competitiveness of northern red oak and to enhance radial growth of both species. At the time of crop tree selection and release following the 1993 growing season, the study stand was 23 years old and black cherry and northern red oak crop trees were about 58 and 47 ft tall, respectively. In 1993, it appeared that the black cherry would eventually overtop the oak and virtually eliminate it from the stand without some kind of management intervention. Crop tree management may be a feasible approach in situations where oak stems are present but may not persist due to faster height growth of competing species. However, the merits of using crop tree management to improve the survival rate of oak when growing in stands with species that exhibit faster height growth remains uncertain due to the variable height growth response of young hardwood crop trees following release. This article presents information that will help forest managers determine if crop tree management is appropriate for enhancing the survival rate of low-density northern red oak growing on productive sites during the early stem exclusion stage.

Study Area

Data were collected on the Fernow Experimental Forest in north-central West Virginia, located in the Allegheny Mountains Section of the Central Appalachian Broadleaf Forest (M221B) (McNab and Avers 1994). The landtype association is referred to as the Allegheny Front Sideslopes, and the vegetation is referred to as mixed mesophytic (Braun 1950). Overstory species composition of second-growth stands is often quite diverse and may include more than 20 species within a spatial scale of about 10 or more acres (Schuler and Gillespie 2000). Common species on the better sites include northern red oak, sugar maple (*Acer saccharum* Marsh.), yellow-poplar, basswood (*Tilia americana* L.), and black cherry. However, species composition in third-growth stands is often less diverse and is regularly dominated by fast-growing shade-intolerant species such as yellow-poplar, black birch (*Betula lenta* L.), and/or black cherry (Brashears et al. 2004). The local climate is characterized by an annual precipitation of 55–58 in. (Pan et al. 1997), a mean temperature of 61.5° F from April through September and 35.1° F from October through March, resulting in 120–140 frost-free days.

The study stand originated following a clearcut regeneration harvest in 1971, totaling 4.25 ac. Sawlogs removed were primarily northern red, chestnut, and white oak (*Q. alba* L.) in descending order of volume. Black birch, yellow-poplar, black cherry, and red maple (*A. rubrum* L.) also were present. Following harvest, all of the slash was pushed from the area with a bulldozer. Care was exercised to avoid deep scarification, and the litter was kept intact over much of the area. The study area originally was used to examine the effects of top-pruning, mulching, and fertilizing on planted northern red oak seedlings of 1–3 years in age (Wendel 1980). Some of the northern red oak crop trees evaluated in this study are from the previous artificial regeneration study, which was terminated in 1979, but past treatments could not be determined for individual trees. The study stand is located on a mostly level broad ridgetop west of Forest Road 701 at an elevation of 2,700 ft (39°3.159′ N, 79°41.157′ W). The soils are mapped as Calvin channery silt loam derived from acid sandstone and shales. They are well drained and have low to moderate natural fertility (USDA Soil Conserv. Serv. 1967). The study area was determined to have a northern red oak site index of about 80 based on height data collected in 1993 (Table 1) and 2003 using equations developed by Wiant and Lamson (1983). The study area also has a black cherry site index of 102 based on Table 1 data and equations developed by Auchmoody and Rexrode (1984). This is indicative of a commercially viable black cherry site.

Methods

The study compartment was divided into four subcompartments of about equal size in which crop trees were selected after the 1993 growing season. At that time, crop trees in two of the subcompartments were released using a conventional crown-touching release (all competing trees whose crowns were touching a crop tree crown were cut) as described by Perkey et al. (1994), while the two remaining subcompartments were retained as untreated areas. Crop trees not adjacent to each other in the treated areas received a four-sided crown-touching release (Perkey et al. 1994), while adjacent crop trees received a three-sided release. All crop trees were required to have a minimum of three sides released. Species preferences were northern red oak, black cherry, and yellow-poplar, in order of priority. All crown classes of northern red oak were acceptable, but only dominant and codominant black cherry and yellow-poplar were acceptable. Crop trees also were required to have a potential for developing a high-quality butt log and no forks or epicormic branches below 17 ft. These criteria were not strictly adhered to for northern red oak because of the desire to retain as many oak stems as possible in the stand.

All crop trees were numbered and initial measurements were taken in November 1993 and again in December 2003. Measurements included diameter at breast height (dbh), crown class, number of epicormic branches at four height intervals, crown radii in four cardinal directions, clear length of stem (defined as the height to the first live branch at least 1 ft long), number of sides released, and total height. Stem length and total height were measured using a tape, clinometer, and standard methodology. Crown radii were used to calculate crown cross-sectional area by summing the two opposing radii and using the resulting axis to calculate the area of an ellipse. In December 2003, all 24 oak crop trees (14 treated and 10 reference) and 30 randomly selected black cherry crop trees (15 treated and 15 reference) were cored at breast height for radial growth analysis. All cores were prepared for ring-width measurements by sanding the surface of the core sample so that the rings could be observed under magnification. Ring-width measurements were performed using a Velmex measuring stage calibrated to 0.01 mm in conjunction with MeasureJ2X V3.1 software to record the ring-width measurement files. Mean ring width series were developed for each of the four categories sampled (treated oak, untreated oak, treated cherry, and untreated cherry). Although the beginning and ending dbh measurements adequately determine radial growth during the 10-year study period, tree-ring measurements graphically illustrate time series trends, which could not have been assessed otherwise.

There were 189 crop trees selected for this study, for an average of about 44 crop trees/acre. Of these, 36 crop trees selected included yellow-poplar, cucumbertree (*Magnolia acuminata* L.), red maple, black birch, and chestnut oak but are not included in the results because of insufficient replication for analysis. It required 10.5 person-hours to complete the crown-touching release operation using chainsaws, slightly more than 2.5 h/ac. Selection of the crop trees occurred prior to the release operation. On average, both black cherry and northern red oak were small pole-size trees in 1993, but black cherry was consistently larger than northern red oak (Table 1).

Data Analysis

Analysis of variance (ANOVA) was used to examine the effects of treatment on the growth of tree height, clear stem length, dbh, and crown cross-sectional area for black cherry and northern red oak. Because the growth of the response variables (e.g., tree height, crown area, etc.) were the dependent variables of interest, repeated measures ANOVA was not used. Subcompartments were used initially as a blocking factor in the experimental design but were dropped from the final analyses because the northern red oak present was not equally distributed among the subcompartments, which limited the power and utility of using a blocking factor. Pearson χ^2 analysis was used to determine if crown class distributions had changed through time with respect to species and treatment; however, the matrices used were sparse and the results were not reliable. As such, crown class distributions are noted in the results but tests of significant change were not feasible.

Table 1. Pretreatment (1993) mean black cherry (BC) and northern red oak (NRO) crop tree characteristics (standard deviation in parentheses) in north-central West Virginia.

Species	Dbh (in.)	Total height (ft)	Stem length (ft)	Crown area (ft^2)	Sample size
BC	7.2 (1.3)	58 (4)	26 (4.4)	685 (309)	123
NRO	5.0 (1.0)	47 (4)	22 (4.8)	470 (226)	24

Results

Total Height and Crown Class

The results of the crop tree release treatment on height growth differed by species. Treated black cherry grew significantly less than untreated black cherry crop trees, while the crop tree release did not affect height growth of northern red oak (Table 2). After the 2003 growing season, northern red oak mean height was 64 ft in the treated areas and 59 ft in the untreated areas, although these means were not significantly different ($P = 0.106$). Black cherry mean height was 70 ft in the treated areas and 74 ft in the untreated areas ($P = 0.001$). Thus, the mean height difference between northern red oak and black cherry of 11 ft in 1993 (Table 1) was reduced to about 6 ft in 2003 within the treated area, but increased to 14 ft in the untreated area.

Prior to release, there were 14 northern red oak crop trees in the treatment block, of which half were classified as codominant crowns and the other half as intermediate crown class trees. After crop tree release and 10 growing seasons, all of the codominant trees retained their competitive stature plus five of the seven intermediate trees progressed to codominants. In the untreated reference group ($n = 10$), one additional oak tree declined from codominant to intermediate stature. The crop tree release had virtually no effect on black cherry crown class distribution. All but one of the black cherry crop trees was codominant in 1993, and only two were reduced to an intermediate crown class position in the following decade, both were in the untreated control group.

Clear Stem Development

Both the treated and untreated black cherry continued to develop additional clear stem length during the 10-year study period, but the rate of development was greater in the untreated group (Table 2). However, this difference did not result in a separation of black cherry total clear length of stem at the last measurement between the treated and untreated groups ($P = 0.538$). Mean black cherry clear stem length in 2003 was 31 ft. After treatment, clear stem development of released northern red oak was about double the rate of the untreated oaks, but the difference was not significant (Table 2). Mean northern red oak clear stem length in 2003 was 29 ft for the released trees and 24 ft for the unreleased trees ($P = 0.089$).

Prior to treatment, no black cherry trees had epicormic branches on the first 17 ft of the stem ($n = 123$). Ten years after crop tree release ($n = 73$), four black cherries developed at least one epicormic branch on the butt log, although all of the untreated crop trees ($n = 50$) remained clear. There was one northern red oak crop tree in 1993 ($n = 24$) with an epicormic branch on the butt log. Ten years after release ($n = 14$), one additional oak developed epicormic branches on the butt log, but three of the untreated reference oaks ($n = 10$) developed butt log epicormic branches. Both of the treated oak crop trees and two of the untreated oak crop trees that developed at least one epicormic branch were classified as intermediate crown class trees.

Crown Area

Crown cross-sectional area increased considerably for both species as a result of the crop tree release (Table 2). Treated black cherry crowns increased more than three times that of untreated trees and treated northern red oak crowns increased more than four times that of untreated trees. By 2003, treated black cherry crowns averaged 1,680 ft^2, whereas untreated black cherry crowns averaged 1,057 ft^2 ($P < 0.001$). The effects of treatment were even more striking for northern red oak. By 2003, treated northern red oak crowns averaged 1,770 ft^2 and untreated crowns were 685 ft^2 ($P = 0.002$).

Diameter Growth

The crop tree release treatment significantly improved diameter growth for both species, but the improvement was somewhat greater for oak (Table 2). By 2003, treated black cherry dbh averaged 10.6 in., whereas untreated black cherry averaged 10.0 in. Treated northern red oak dbh averaged 8.7 in. 10 years after release, and untreated oak averaged 6.7 in. Graphical analysis of radial growth between treated and untreated northern red oak crop trees suggests the treatment effect has not yet subsided (Fig. 1). Northern red oak radial growth rates for treated trees from 1998 to 2003 were equivalent to about 3 in. of diameter growth per decade, or about twice that of untreated trees. In contrast, black cherry response was most evident during the first 5 years after treatment, but radial growth rates have converged in the last 5 years (Fig. 1).

Table 2. Mean 10-year growth response of treated and untreated crop trees in north central West Virginia (BC = black cherry and NRO = northern red oak). *P* value is from an analysis of variance comparing treated versus untreated crop trees by species.

Growth	Species	Treatment	Mean growth response	*P* value
Total height (ft)	BC	Untreated	16.1	
		Treated	11.4	<0.01
	NRO	Untreated	13.9	
		Treated	15.5	0.51
Clear stem length (ft)	BC	Untreated	6.8	
		Treated	4.0	0.02
	NRO	Untreated	3.1	
		Treated	5.7	0.30
Crown area (ft^2)	BC	Untreated	306	
		Treated	1,049	<0.01
	NRO	Untreated	264	
		Treated	1,264	<0.01
Dbh (in.)	BC	Untreated	2.8	
		Treated	3.5	<0.01
	NRO	Untreated	1.9	
		Treated	3.6	<0.01

Discussion

This study demonstrates that crop tree release should increase the likelihood of northern red oak persistence in pole-size stands, in part by reducing black cherry height growth and freeing up growing space that northern red oak can readily use, perhaps even more so than black cherry. As a result of a crown-touching release, black cherry crop trees slowed in height growth by about 30% during the last decade, while height growth of northern red oak was not

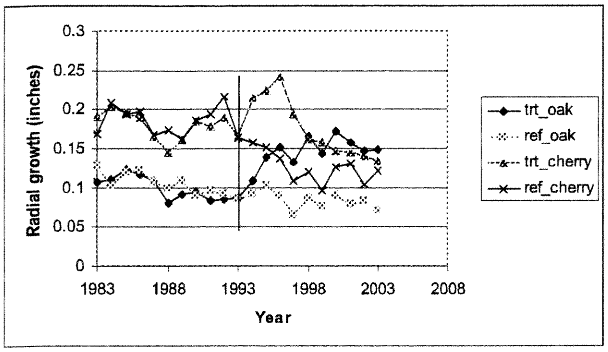

Figure 1. Crop tree mean annual radial growth (in.) of released (three or more sides) northern red oak (trt_oak), untreated northern red oak (ref_oak), released black cherry (trt_cherry), and untreated black cherry (ref_cherry) in a crop tree study in West Virginia. (Note: Diameter growth can be estimated as double the radial growth.)

affected and grew in accordance with published site index equations (Wiant and Lamson 1983). During the decade following treatment, released northern red oak crop trees exceeded the height growth of released black cherry, and released northern red oak more than quadrupled its crown area relative to unreleased oak crop trees. The significant increase in oak crop tree crown area (a surrogate for foliar area) may also explain the continued higher rate of radial stem growth 10 years after treatment, which was about double the rate of unreleased oak crop trees. A larger crown area also makes it more difficult for other trees to overtop the desired crop tree.

Crop tree release leading to less competition, larger crowns, and sustained height growth also improved oak crown class distribution. A decade after treatment, about 86% of the treated oak crop trees were classified as codominants. Moreover, 70% of intermediate crown class trees that were released in 1993 were classified as codominants in 2003. Managers need more information about releasing intermediate crown class oaks in young even-aged stands on productive sites. This study only begins to address the issue but suggests that it is feasible to improve the competitive stature of intermediate oaks. The cultural practice of releasing oak crop trees also may simulate past disturbance regimes when old-growth oak forests developed. In a recent study, oaks growing in old-growth forests often exhibited periods of suppression and release before gaining overstory status (Rentch et al. 2003), further evidence that releasing intermediate and codominant oak crop trees mimics past stand dynamics.

The perpetuation of northern red oak in mixed-oak forests, an important forest management issue in the eastern and central United States, is being addressed in several different ways. Much of the research concerning the sustainable management of oak has focused on the development of natural regeneration methods and guidelines in conjunction with regeneration harvests (e.g., Sander et al. 1976, Loftis 1990, Brose et al. 1999). In many cases, where stands do not meet the suggested guidelines, oak may be present after a regeneration harvest but often does not persist long after crown closure (Brashears et al. 2004). A recent survey of postclearcut regeneration units up to 30 years old on the Monongahela National Forest documented about 10–40 overstory northern red oak trees/acre in the oldest regeneration units (Miller et al. 2001). However, the number of northern red oak stems found declined consistently with stand age (e.g., 10, 20, and 30 years since harvesting), illustrating the need to actively manage for retention of this species during the early stem exclusion period if the retention of oak is a management objective. The survival rate of young northern red oak growing in fully stocked stands that consist primarily of fast growing species such as yellow-poplar and black cherry is unknown (i.e., third-growth forests developing today), but it is likely less than the survival rate of oak growing in stands where oaks competed for growing space with a variety of other species, including a greater percentage of oak (i.e., second-growth stands that developed following the logging of old-growth stands in the early 1900s). For example, in this study, the calculated site indices of northern red oak (80) and black cherry (102) represent a projected 22-ft height advantage for black cherry at age 50 in the absence of cultural treatments. Such a significant height advantage for black cherry may virtually eliminate northern red oak from the stand, if left untreated, as black cherry crowns expand and overtop the relatively few oaks. Brashears et al. (2004) demonstrated a similar scenario where yellow-poplar became the overwhelming dominant species in young stands, excluding most other species that were not shade-tolerant. In New England, some studies have shown that oaks can recover in the later stages of stand development due to stiffer lateral branches, giving oak an advantage in competition for the upper canopy; however, branch stiffness in oaks may not be sufficient to overcome large differences in height growth potential (Oliver and Larson 1996). If a northern red oak tree is overtopped during the early stages of stand development in an even-aged stand when the upper canopy remains unbroken for decades, it is likely to die before it has a chance to compete for an upper canopy position later in stand development when the canopy structure becomes more complex. Moreover, while some oaks may survive to the later stages of stand development even without crop tree release, the objective in this study was to evaluate the potential for increasing the number, size, and relative importance of northern red oak in stands harvested during the past 20–30 years.

The results reported in this study are partially corroborated by the results of previous research. In studies in New England and the Central Appalachians, northern red oak did not exhibit height growth suppression when fully released (Ward 1995, Miller 2000). Moreover, both black cherry and yellow-poplar crop tree height growth was reduced when treated with a slightly heavier thinning (all competing trees whose crowns were within 5 ft of a crop tree crown were cut) than a conventional crown-touching release (Miller 2000). Although the results reported here and that of Miller (2000) differ in the degree of release needed to inhibit height growth of black cherry, both studies illustrate black cherry height growth is sensitive to growing space and can be suppressed by cultural treatments.

In large sapling and pole-size even-aged stands where northern red oak is not likely to persist due to competition from other species, the results reported here and the work of others previously noted illustrate crop tree management can be an effective tool for enhancing northern red oak competitiveness. To do so, forest managers should use a crown-touching release for northern red oak and a slightly more aggressive release for black cherry and/or yellow-poplar, such as removing any tree whose crown is within 5 ft of the crop tree. Although a simple crown-touching release inhibited black cherry height growth in this study, the short-term effect on black cherry radial growth and the work of Miller (2000) suggest a slightly heavier thinning would further enhance black cherry radial growth and suppress its height growth. Pole-size or large sapling-size stands at least 25 ft tall should be targeted for enhancing oak competitiveness with crop tree management.

Opportunities for using this technique in young even-aged stands are abundant (Miller et al. 2001) and can be identified by sampling species composition, crown class, and relative stem density of even-aged regeneration units. While in many situations opportunities to implement regeneration strategies prior to harvesting are limited (Fajvan et al. 1998), crop tree management as suggested here provides another opportunity to increase northern red oak competitiveness and relative abundance in young even-aged stands following conventional clearcutting conducted in the past 10–30 years. Doing so may represent one of the most cost-effective means of enhancing the relative abundance of oak in today's younger forests.

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